PhD Program in Bioengineering and Robotics

Curriculum in Robotics and Autonomous Systems

Research themes

The main goal of the PhD curriculum in *Robotics and Autonomous Systems* is to study, design and build novel solutions and behaviors for robots, teams of robots and, in general, autonomous systems capable of exhibiting a high degree of autonomy and intelligence when performing highly complex tasks in challenging real-world environments.

The focus of the curriculum is two-fold: on the one hand, on key, innovative and disruptive methodologies and technologies, including such topics as sensing, state estimation, knowledge representation, software architectures for robots, real-time scheduling, motion planning, advanced robot control, robot coordination and cooperation, human-robot interaction and collaboration, design of macro/micro robot systems, design of sensors and actuators; on the other hand, on specific areas, e.g., underwater operations, aerial and space, or Industry 4.0, as well as on such diverse application scenarios as manufacturing, material handling and transportation, search & rescue, surveillance and monitoring, ambient assistive living).

The curriculum enforces research practices and education methodologies based on cutting-edge best practices at the international levels, and all the aspects outlined above are dealt with by focusing on the study and the adoption of theoretically sound methodologies and the design of experimentally verifiable solutions, with the goal of meeting robustness and predictability requirements even in unknown, dynamically changing, or even hazardous environments.

The research topics offered in this intake are aimed at being carried out primarily as part of research teams and labs of the Department of Informatics, Bioengineering, Robotics and System Engineering at the University of Genoa, and when explicitly stated, jointly with other research institutions and companies worldwide. In particular, for this intake, the curriculum offers topics related to human-robot interaction and collaboration (topics 1, 3, 7, 13, 14 and 16), tactile sensing (topics 2, 4), object manipulation (topics 5), control of teams of drones (topic 6) naturalness in interaction (topics 7, 8 and 13), underwater robotics (topics 9, 10), robots and virtual/augmented reality (topics 9 and 17), state estimation methods (topics 11, 12) cognitive systems (topics 8, 15) and multi-robot cooperation and reasoning (topics 15). The curriculum also offers two industrial doctorate positions funded by LEONARDO Company (topics 18, 19).

The ideal candidates are students with a higher-level University degree, with a strong desire for investigating, designing and developing robot-based systems which can have a huge, disruptive, impact on the society in the upcoming future.

International applications are strongly encouraged and will receive logistic support with visa issues and relocation.

1. Sensor-based control of robots for human-robot cooperative operations

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Description:

Innovative robot systems are expected to work and cooperate with other robots and humans for the execution of handling and manipulation tasks for industrial and service applications. To this aim highly sensorized robots are required to execute collaborative tasks safely side by side with humans and are expected to properly react to unexpected events as well as to estimate the human intentions or the changes within their working envelope to ensure the reliable and safe (in case of direct interaction with humans) execution of the planned tasks. Highly sensorized robot systems, or robot working cells (depending on context and application), typically feature multiple camera sensors, range sensors, tactile and force/torque sensors, and possibly task specific sensing devices.

This doctorate project is part of the European Project Collaborate (https://collaborate-project.eu). The goal is to study robot control methods based on multisensory feedback (joint visuo-tactile feedback) for collaborative human-robot assembly operations for car assembly.

These research topics have been part of relevant international research projects (Collaborate: https://collaborate-project.eu; CloPeMa: www.clopema.eu).

Requirements:

Applicants are expected to have very good skills in at least two of the follwong areas: software development, robot control, robot programming, mechatronics. Furthermore, good attitude for experimental work is mandatory. The candidates must have: very good programming skills with different languages (including C/C++, Python, Matlab/Simulink); confidence with electronic hardware and be capable to conduct experiments; attitude to problem solving, and be strongly motivated for team working.

References:

[1] G. Cannata, S. Denei, F. Mastrogiovanni. Towards the creation of tactile maps for robots and their use in robot contact motion control. Robotics and Autonomous Systems 63(3): 293–308, 2015.
[2] S. Denei, F. Mastrogiovanni, G. Cannata. Parallel Force-Position Control Mediated by Tactile Maps for Robot Contact Tasks. Proceedings of the 2012 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2012), Vilamoura, Portugal, October 2012.
[3] Albini, G. Cannata. Pressure distribution classification and segmentation of human hands in contact with the robot body. The International Journal of Robotics Research, 2020.

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2. Robot skin for contact processing and robot control

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Description:

Novel applications require humans and robots supporting each other to execute complex tasks in unstructured environments. In such a scenario, different types of contacts or collisions with humans or the environment can occur. Robot skin systems allow to capture these complex contact phenomena, opening new scenarios on contact processing, both for control and cognitive level processing, enabling the interpretation of physical contacts.

In principle, the robot skin would enable the realization of high-level robot behaviours. Indeed, depending on the information extracted from the contact, the robot can react accordingly.

This doctorate project is part of the European Project Collaborate (https://collaborate-project.eu). The goal is to study techniques to process and classify tactile data feedback and to extract information that can be used to command specific robot motions, thus enhancing the collaboration between humans and robots.

Requirements:

Applicants are expected to have very good skills in at least two of the follwong areas: software development, robot control, robot programming, mechatronics. Furthermore, good attitude for experimental work is mandatory. The candidates must have: very good programming skills with different languages (including C/C++, Python, Matlab/Simulink); confidence with electronic hardware and be capable to conduct experiments; attitude to problem solving, and be strongly motivated for team working.

References:

[1] Albini, G. Cannata. Pressure distribution classification and segmentation of human hands in contact with the robot body. The International Journal of Robotics Research 2020.
[2] G. Cannata, S. Denei, F. Mastrogiovanni. Towards the creation of tactile maps for robots and their use in robot contact motion control. Robotics and Autonomous Systems 63(3): 293–308, 2015.

[3] S. Denei, F. Mastrogiovanni, G. Cannata. Parallel Force-Position Control Mediated by Tactile Maps for Robot Contact Tasks. Proceedings of the 2012 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2012), Vilamoura, Portugal, October 2012.

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3. Multimodal Sensing for Robot Self-aware Control

Tutors:

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Description:

Robot manipulators in industrial and service applications are controlled assuming a complete knowledge of the robot workspace. This requires a-priori models or extensive sensorization of the robot’s workcell. The objective of the project is to study and develop sensing and control technologies and algorithms to enable the robot to localize itsels with respect to the surrounding environment and to safely interact with objects, other robots or humans with a limited need of external sensors. The advantage of this solution is to reduce the costs, and the set-up time of robotic workcells towards the development of plug and play robot systems.

The goal of this Doctorate project is to investigate algorithms, also based on machine learning solution to build a space representation of the environment surrounding the robot using proximity and tactile sensors covering the robot and to exploit the feedback provided by these sensors to execute safely standard tasks (such as pick and place, assembly of parts etc.), but also new types of operations (e.g. whole arm manipulation).

Requirements:

Applicants are expected to have very good skills in at least two of the following areas: software development, robot control, robot programming, mechatronics. Furthermore, good attitude for experimental work is mandatory. The candidates must have: very good programming skills with different languages (including C/C++, Python, Matlab/Simulink); confidence with electronic hardware and be capable to conduct experiments; attitude to problem solving, and be strongly motivated for team working.

References:

[1] S. Denei, P. Maiolino, E. Baglini, G. Cannata. Development of an integrated tactile sensor system for clothes manipulation and classification using industrial grippers. IEEE Sensors 7 (19), 6385-6396
[2] G. Cannata, S. Denei, F. Mastrogiovanni. Towards the creation of tactile maps for robots and their use in robot contact motion control. Robotics and Autonomous Systems 63(3): 293–308, 2015.

[3] P. Maiolino, M. Maggiali, G. Cannata, G. Metta, L. Natale. A Flexible and robust large scale capacitive tactile system for robots. IEEE Sensors Journal, vol. 13, no. 10, pp. 3910-3917, October 2013.

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4. Machine learning models for robot tactile sensing and perception

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Description:

Tactile sensing is one key topic for the development of future robots capable of complex interaction with humans and objects. Design of tactile sensors as well as tactile based sensing, perception and control are challenging research topics and University of Genova has gained a solid reputation in this area in the past few years, and has been involved in important international research projects related to this topic (ROBOSKIN: www.roboskin.eu; CloPeMa: www.clopema.eu).

Tactile data convey information about the characteristics of the contact between the robot and the manipulated objects. This information is fundamental to proper control the grasping and manipulation; furthermore, controlled manipulation can in turn be used to extract further information useful to recognize and classify objects and contacts.

The objective of the PhD program is to investigate techniques and methodologies for tactile data sensing, perception and interpretation. Furthermore, since tactile data are generated by active manipulation control another objective is the study of the mechanisms relating tactile based feedback robot control and tactile data perception.

Requirements:

Applicants are expected to have strong background and experience in at least one of the following topics: robot control, machine learning, system identification. The candidates must have: very good programming skills with different languages (including C/C++, Matlab/Simulink); experience with electronic hardware; be capable to conduct experiments and be strongly motivated for team working.

References:

[1] G. Cannata, S. Denei, F. Mastrogiovanni. Towards the creation of tactile maps for robots and their use in robot contact motion control. Robotics and Autonomous Systems 63(3): 293–308, 2015.

[2] P. Maiolino, M. Maggiali, G. Cannata, G. Metta, L. Natale. A Flexible and robust large scale capacitive tactile system for robots. IEEE Sensors Journal, vol. 13, no. 10, pp. 3910-3917, October 2013.
[3] L. Muscari, F. Mastrogiovanni, L. Seminara, M. Capurro, G. Cannata, M Valle. Real-time reconstruction of contact shapes for large area robot skin. Proceedings of the 2013 IEEE International Conference on Robotics and Automation (ICRA 2013), Karlsruhe, Germany, May 2013.

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5. Robot manipulation of soft and flexible objects

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Description:

Highly sensorized robots are expected to execute highly coordinated motions to handle and manipulate soft and flexible objects (e.g. cables, fabrics etc.) autonomously or in cooperation with other agents (either robots or humans). These operations require a modelling of the manipulated objects along with sensors based (vision and touch) estimation algorithms to predict their deformation and to generate appropriate control strategies. Examples of relevant tasks of this class for industrial or service applications include, but are not limited to: handling of cables, assembly, packaging, co-operative human robot handling of non rigid/deformable objects, etc.

These research topics have been part of relevant international research projects (Collaborate: https://collaborate-project.eu/; CloPeMa: www.clopema.eu).

Requirements:

Applicants are expected to have a strong motivation for at least one of the following key topics in robotics: robot control, robot programming, system identification. Furthermore, good attitude for experimental work is mandatory. The candidates must have: very good programming skills with different languages (including C/C++, Python, Matlab/Simulink); confidence with electronic hardware and be capable to conduct experiments; attitude to problem solving, and be strongly motivated for team working.

References:

[1] G. Cannata, S. Denei, F. Mastrogiovanni. Towards the creation of tactile maps for robots and their use in robot contact motion control. Robotics and Autonomous Systems 63(3): 293–308, 2015.
[2] S. Denei, F. Mastrogiovanni, G. Cannata. Parallel Force-Position Control Mediated by Tactile Maps for Robot Contact Tasks. Proceedings of the 2012 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2012), Vilamoura, Portugal, October 2012.
[3] A. Del Prete, S. Denei, L. Natale, F. Mastrogiovanni, F. Nori, G. Cannata, G. Metta. Skin spatial calibration using force/torque measurements. Proceedings of the 2012 IEEE/RSJ

International Conference on Intelligent Robots and Systems (IROS 2012), Vilamoura, Portugal, October 2012.

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6. Team of drones for periodic monitoring: an approach based on social drone sharing.

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Description:

Multirotor drones may play a crucial role in many applications, related both to

- the periodic monitoring of industrial plants and structures (e.g., power lines) and infrastructures (e.g., highways), as well as
- the management of emergencies, including earthquakes, fires, and damaging hydrogeological events.

In this context, the quantity and quality of the information acquired on the field, and its availability to decision makers in short time, may play a crucial role to limit the environmental, social, and economic damages.

The PhD research has the main objective of developing guidelines, methods, and algorithms to coordinate teams of multirotor autonomous drones for monitoring plants, structures, infrastructures, and any other areas that can be subject to damage or emergencies [1, 2]. During periodic monitoring, the information acquired by autonomous drones through sensors (e.g., RGB or thermal cameras) may return a high resolution monitoring of the variables describing the phenomena of interest, with the objective of scheduling a human intervention. During an emergency, drones may monitor in real-time the area affected by the event to optimize the allocation of human resources and provide information to the population. After an emergency, drones may map damaged areas in order to mitigate effects and coordinate rescue operations [3].

Many typologies of multirotor drones are available on the market. Most systems allow the user to communicate to the drone a flight plan (possibly modifiable through 4g communication), which then will be followed in autonomy by the drone. However, state-of-the-art multirotor drones have very hard constraints concerning energetic autonomy, which impact on the maximum flying time (between 15 and 30 minutes). On its turn, this has a consequent impact on the maximum areas that can be covered, and raises a number of research issues [4, 5]:

- How is it possible to overcome limitations concerning energetic autonomy, which are inherent in the current multirotor technology, by using properly coordinated teams of drones instead of single drones?
- What policies, software architecture and algorithms shall be implemented in order to automatically compute and coordinate the flight plans of drones in the team, to the final aim of monitoring an assigned area with given requirements in terms of (i) dimensions of the area, (ii) frequency of monitoring, (iii) resolution of monitoring?
- How can we address all the unsolved problems related to autonomous flight, including automatic processing and storage of sensor data acquired during the mission, sensor-based localization, navigation, visual servoing and control?
- How is it possible to involve private citizens in this process, in a “social sharing of responsibility” where residents located on the territory are responsible of the maintenance of drones, keeping them fully charged, preparing them for take-off when needed, receive them during landing, etc.

From an implementation perspective, these issues will be addressed different multirotor drones, including a team of 5 small DJI Tello (for lab experiments) and 2 DJI Mavic Pro (for field experiments), a small yet powerful drone with 30 minutes autonomy which offers up to 7km of transmission range, fly at up to 64kmh for as long as 27 minutes, provides 4K gimbal-stabilized video to ensure smooth footage, and can fly by Phone over Wi-Fi for even easier flight.

This PhD targets to take a leap forward with respect to State-of-the-art by developing, for the first time ever, a framework for Social Drones Sharing, capable of managing all the activities that drones for autonomous monitoring are expected to exhibit and paving the way to a new way of interpreting drone technology for the major benefit of the community.

The research group in which the PhD will work has a strong experience in wearable systems and autonomous drones for Search&Rescue thanks to the ongoing DIONISO National project and the previous PRISMA project. The candidate will have access to the resources of the EMAROlab (https://masteremaro.ec-nantes.fr/) and the Social Robotics Lab of University of Genova.

A period of research abroad in a foreign institution or company in Europe, USA or Asia (ranging from 6 to 12 months) may be explored depending on the candidate availability.

Requirements:

Applicants are expected to have good programming skills (possibly including Python, C/C++, Matlab/Simulink), a strong motivation for studying and making research, attitude to problem solving, and be strongly motivated for team working.

References:

[1] Otto, A., Agatz, N., Campbell, J., Golden, B., Pesch, E. Optimization approaches for civil applications of unmanned aerial vehicles (UAVs) or aerial drones: A survey (2018) Networks, 72 (4), pp. 411-458.

[2] Floreano, D., Wood, R.J. Science, technology and the future of small autonomous drones (2015) Nature, 521 (7553), pp. 460-466.
[3] Recchiuto, C. T., & Sgorbissa, A. (2018). Post-disaster assessment with unmanned aerial vehicles: A survey on practical implementations and research approaches. Journal of Field Robotics, 35(4), 459-490.
[4] Erdelj, M., & Natalizio, E. (2016, February). UAV-assisted disaster management: Applications and open issues. In 2016 international conference on computing, networking and communications (ICNC) (pp. 1-5). IEEE.
[5] Khoufi, I., Laouiti, A., Adjih, C. A survey of recent extended variants of the traveling salesman and vehicle routing problems for unmanned aerial vehicles (2019) Drones, 3 (3), art. no. 66, pp. 1-30.

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7. Cooperation and Social Interaction with Autonomous Humanoids.

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Description:

Autonomous robots are becoming more and more popular for a wide range of applications ranging from education to elderly care, as it is shown by the success of recent systems available on the market, as well as the number of research projects in the field, such as the H2020 CARESSES[1][2] project led by University of Genova.

However, in spite of their incredible "appeal" and superior capabilities, social robots still lack many important skills, including the capability to safely move in the environment by perceiving their surroundings and interact with people in a fully autonomous way both verbally and non-verbally.

Indeed, the development of advanced capabilities enabling robots to efficiently cooperate with humans in non-industrial environments necessarily requires the integration of results from different areas of research, including those that are traditionally related to Artificial Intelligence and Robotics (i.e., in the field of Machine Learning, Planning, Control, Knowledge Representation, Natural Language Processing, Human-Machine Interaction) as well as those that are related to Cognitive Science and Psychological studies (i.e., in the field of Cognitive Modelling, Affective Computing, User Interface Design) and Ethics. Experience shows that, without addressing all these aspects in an integrated way, all attempts to design fully autonomous robots capable to successfully interact with humans and their environment are doomed to fail.

According to this rationale, this PhD research program will address one or more research questions, to be chosen among the following or additional different ones suggested by the candidate:

- What methods and algorithms can we implement for human-aware autonomous navigation in a crowded social environment [1, 2], allowing the robot to safely achieve its own objectives by taking socio-cultural norms as well as safety constraints into account? How is it possible to generate natural and human-like trajectories in presence of obstacles, in order to induce in surrounding humans a sense of familiarity and trust? How can the robot use

[1] CARESSES, "EU-Japan H2020 Project CARESSES," http://caressesrobot.org.

[2] EU CORDIS, "The world's first culturally sensitive robots for elderly care," https://cordis.europa.eu/article/id/124441-the-worlds-first-culturally-sensitive-robots-for-elderly-care.

verbal and non-verbal behaviour (arm and head gestures) to communicate with surrounding humans in case that a negotiation or help is needed (a narrow passage which requires the human and the robot to negotiate or an obstacle that cannot be avoided without human help)?

- How can the robot infer the user's emotion and intentions [3] by relying on verbal and non-verbal signals (human body posture and movement, gesture, direction of the gaze, distance from the robot, pauses in speech, volume of the voice), given the available technology in sensing and recognition? How can the detected attitude of the user be exploited to adapt the behaviour of the robot to interact with him/her in the most appropriate way? How can the robot use similar models to express emotions [4]?
- What methods and algorithms can we implement to allow humans and robots to physically cooperate towards the achievement of a given task, for instance for passing each other an object (a task trivial for humans but is still very challenging for robots) [5]? What is the best way for the robot to give the object to the human and vice versa, so that object hand-over is comfortable for the person (e.g., what is the optimal approaching direction, distance and the direction of the arm holding the object)? how to find a mutual agreement such that the agent keeping the object can safely release it (e.g., what are the signals allowing the robot to understand that the human is holding the object and ready to receive it)?
- What is the role played by Theory of Mind (ToM) [4] in the interaction between human and robots, that is the ability to attribute independent mental states to self and others, to the end of predicting and explaining behaviors? How is it possible to adapt the behaviour of the robot in order to increase the trust that the human partner has in its robotic companion? How is it possible to restore trust after a failure?
- What applications domains can have the greatest benefit from social humanoid robots and are worth being explored?

The Phd candidate will address one or more of the research questions above (or similar research questions in this area) by using the robot Pepper by SoftBank Robotics, a very popular and versatile humanoid robot with 20 degrees of freedom. Concerning sensors, the robot's head has four microphones, two HD cameras (in the mouth and forehead), and a 3-D depth sensor (behind the eyes). A gyroscope is located in the torso and touch sensors in the head and hands. The mobile base has two sonars, six lasers, three bumper sensors, and a gyroscope. As an alternative / additional platform, SoftBank NAO will be considered, that shares the same NAOqi operating system with Pepper [7]

The research group in which the PhD will work has a strong experience in autonomous robots for social interaction thanks to their work in the H2020 CARESSES project, the recently started IENE10 project, as well as many additional research programs the research group was involved in the last tears. The candidate will have access to the resources of the EMAROlab (https://masteremaro.ec-nantes.fr/) and the Social Robotics Lab of University of Genova.

A period of research abroad in a foreign institution or company in Europe, USA or Asia (ranging from 6 to 12 months) may be explored depending on the candidate availability.

Requirements:

Applicants are expected to have good programming skills (possibly including Python, C/C++, Matlab/Simulink), a strong motivation for studying and making research, attitude to problem solving, and be strongly motivated for team working.

References:

[1] Sisbot, E.A., Marin-Urias, K.F., Alami, R., Siméon, T., A human aware mobile robot motion planner (2007) IEEE Transactions on Robotics, 23 (5), pp. 874-883.

[2] Thibault Kruse, Amit Kumar Pandey, Rachid Alami, Alexandra Kirsch, Humanaware robot navigation: A survey, Robotics and Autonomous Systems 61 (2013) 1726-1743

[3] Kleinsmith, A., Bianchi-Berthouze, N., Affective body expression perception and recognition: A survey, IEEE Transactions on Affective Computing, 4(1), 2013

[4] Cynthia Breazeal, Emotion and Sociable Humanoid Robots, International Journal of HumanComputer Studies, 2003

[5] J. Mainprice, M. Gharbi, T. Siméon and R. Alami, "Sharing effort in planning human-robot handover tasks," 2012 IEEE RO-MAN: The 21st IEEE International Symposium on Robot and Human Interactive Communication, Paris, 2012, pp. 764-770.

[6] Scassellati, B. (2002). Theory of mind for a humanoid robot. Autonomous Robots, 12(1), 13-24.

[7] NAOqi Developer guide: http://doc.aldebaran.com/2-5/index_dev_guide.html

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8. Culture-Aware Artificial Intelligence and Embodied Intelligent Systems.

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Description:

Artificial Intelligence, in the last decade, has become pervasive in all aspects of our lives, experiencing a fast process of commodification and reaching the society at large. This process includes the development of a new generation of robotic and embodied intelligent systems, equipped with the capability to interact and cooperate with humans not just visually and vocally but also physically.

In this general scenario, AI-based systems will need to be able to integrate themselves not only in a functional way (i.e., delivering what they are requested to) but also in a culture-aware way (i.e., adapting to the cultural background of people in order to deliver their services with cultural sensitivity). This requires the definition of algorithms able to behave differently based on the particular cultural context (or mix of cultural contexts) in which they are placed, while avoiding a stereotyped representation of people and culture. At the same time, knowing the cultural biases that affect human beings in interpreting perceptions, taking decisions, and interacting with each other, will allow computer scientists and engineers to design new AI-based systems able to improve their performance by exploiting the experience gained from different cultural environments.

In the last years, global initiative towards more Human AI (e.g., https://www.humane-ai.eu/) are getting more attention both from academic research and the industry, since they target the increased concerns about the impact of AI in society: that is, the fear that AI is putting at risk fundamental human rights like privacy, explainability, and fairness, and has shown to be potentially easily fooled by adversaries [1,2]. Cultural factors in AI have been partially investigated as well, particularly in Robotics [3]: all previous approaches focused on individual features that can make the system more or less acceptable to people of different cultures, either concerning its appearance or its behavior [4, 5, 6], including verbal and non-verbal interaction [7, 8, 9] or social distance [10, 11]. However, with few exceptions [12, 13], none of the earlier approaches aimed to define a general conceptual framework to make an intelligent system culture aware. Indeed, despite these initial attempts, culture-aware AI is still largely unexplored, and are expected to become a hot topic in the close future - as also proved by the increased interest towards this area in the forthcoming Horizon Europe funding program.

This PhD targets to take a leap forward with respect to State-of-the-art, proposing to develop an AI, for the first time ever, able to be not just trustable but also culture-aware, namely being able to behave differently based on the cultural context in which it has been employed, allowing a new level of integration between humans and AI-based systems.

The research group in which the PhD will work has a strong experience in culture-aware Robotics thanks to the recent H2020 CARESSES[3][4] project, as well as in FAIR AI and Machine Learning, thanks to recent two Amazon Machine Learning Awards[5]. The candidate will have access to the resources of the EMAROlab (https://masteremaro.ec-nantes.fr/), the Social Robotics Lab of University of Genova, and the SmartLab of the University of Genova.

A period of research abroad in a foreign institution or company in Europe, USA or Asia (ranging from 6 to 12 months) may be explored depending on the candidate availability.

Requirements:

Applicants are expected to have good programming skills (possibly including Python, C/C++, Matlab/Simulink), a strong motivation for studying and making research, attitude to problem solving, and be strongly motivated for team working.

References:

[1] L. Oneto and S. Chiappa. "Fairness in machine learning." Recent Trends in Learning From Data. Springer, Cham, 2020. 155-196.

[2] B. Biggio and F. Roli. "Wild patterns: Ten years after the rise of adversarial machine learning." Pattern Recognition 84 (2018): 317-331.

[3] M. Rehm, "From multicultural agents to culture-aware robots," in Lecture Notes in Computer Science, 2013, pp. 431-440.

[4] T. Shibata et al., "Cross-cultural studies on subjective evaluation of a seal robot," Adv Robotics, vol. 23, no. 4, pp. 443-458, 2009.

[5] P. Rau, Y. Li and D. Li, "A cross-cultural study: Effect of robot appearance and task," International Journal of Social Robotics, vol. 2, no. 2, pp. 175-186, 2010.

[6] H. Lee et al., "Pepper or roomba? Effective robot design type based on cultural analysis between Korean and Japanese users," Int J Soft Eng its Appl, vol. 10, no. 8, 2016.

[7] S. Andrist et al., "Effects of Culture on the Credibility of Robot Speech: A Comparison between English and Arabic," in HRI 2015, 2015.

[8] P. Rau et al., "Effects of communication style and culture on ability to accept recommendations from robots," Comput Hum Behav, vol. 25, no. 2, pp. 587-595, 2009.

[9] M. Rehm, "Affective body movements (for robots) across cultures," Intell Syst Ref Libr, vol. 134, pp. 165-188, 2018.

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[3] CARESSES, "EU-Japan H2020 Project CARESSES," http://caressesrobot.org.

[4] EU CORDIS, "The world's first culturally sensitive robots for elderly care," https://cordis.europa.eu/article/id/124441-the-worlds-first-culturally-sensitive-robots-for-elderly-care.

[5] https://www.amazon.science/research-awards/success-stories/algorithmic-bias-and-fairness-in-machine-learning

[10] G. Eresha et al., "Investigating the influence of culture on proxemic behaviors for humanoid robots," RO-MAN 2013, 2013.
[11] M. Joosse et al., "Cultural differences in how an engagement-seeking robot should approach a group of people," in CABS 2014, 2014.
[12] Bruno, B., Chong, N.Y., Kamide, H., Kanoria, S., Lee, J., Lim, Y., Pandey, A.K., Papadopoulos, C., Papadopoulos, I., Pecora, F., Saffiotti, A., Sgorbissa, A. Paving the way for culturally competent robots: A position paper (2017) RO-MAN 2017 - 26th IEEE International Symposium on Robot and Human Interactive Communication, 2017-January, pp. 553-560.
[13] Bruno, B., Recchiuto, C.T., Papadopoulos, I., Saffiotti, A., Koulouglioti, C., Menicatti, R., Mastrogiovanni, F., Zaccaria, R., Sgorbissa, A., Knowledge Representation for Culturally Competent Personal Robots: Requirements, Design Principles, Implementation, and Assessment (2019) International Journal of Social Robotics, 11 (3), pp. 515-538.

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9. Obstacle detection, tracking and avoidance in maritime environments

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Co-Tutors: Francesca Odone

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Description:
Recently, there has been considerable interest in the development of unmanned surface vehicles (USVs) due to their increasing demand in various maritime applications. One of the main capabilities that unmanned vehicle must be endowed with is a robust, reliable, effective and real-time guidance, navigation, and control (GNC) system. The ability to detect, recognize and track different targets and obstacles in real-time is strongly required in order to reliably operate in the complex and dynamic marine environment, where environmental disturbances (winds, waves, and currents), sea fog, lighting conditions, and water reflection, have a great impact on the performance of the perception system.

The goal of this Ph.D. proposal is twofold. On the one hand, research in multi-sensor detection and tracking is needed. Previous works have started lying down a possible detection and tracking pipeline based on camera and a LIDAR [1], using a state-of-the-art object detection CNN (Convolutional neural network) YOLO [2]. Further improvements can be reached including a thermal camera and considering alternative GPU architectures such as nvidia Xavier or Google Coral. On the other hand, once the tracking is performed, the GNC of the vehicle should take this information into account to autonomously avoid the obstacle [3]. This proposal can exploit the ULISSE catamaran for the experimental validation [1].

Requirements: Good programming skills (Matlab, Python or C++); Background knowledge in computer vision and machine learning.

References:

[1] Mina Sorial, Issa Mouawad, Enrico Simetti, Francesca Odone, Giuseppe Casalino, Towards a Real Time Obstacle Detection System for Unmanned Surface Vehicles, OCEANS 2019, Seattle
[2] Joseph Redmon, Ali Farhadi: YOLOv3: An Incremental Improvement (and references therein)
[3] Casalino, G., Turetta, A., & Simetti, E. (2009, May). A three-layered architecture for real time path planning and obstacle avoidance for surveillance USVs operating in harbour fields. In Oceans 2009-Europe (pp. 1-8). IEEE.

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10. Advanced underwater robotic operations: cooperative control of an autonomous surface vehicle and a tethered remotely operated vehicle

Tutors:

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Enrico Simetti

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Description:
ROV (Remotely Operated Vehicles) class underwater vehicles are submarine robots remotely piloted through an umbilical (tether) that connects them to a command station on the surface. The umbilical is used to exchange commands and data between the command station and the ROV. On some platforms, the tether is also used to transport the electricity needed by the ROV. Otherwise, if the robot is equipped with batteries or a form of power supply on board, the umbilical is used for communications only. In any case it is necessary to control the quantity of cable released from the reel as a function of the relative position between the control station and the ROV and as a function of their relative motion. Cable management must also take into account the dynamic loads on the tether and the presence of obstacles (including the ROV itself). In large ROV operations, cable management is mediated by a specific device known as the Tether Management System (TMS), while for smaller ROVs the umbilical is managed by a manually operated reel.

The aim of the study is to develop cooperative control solutions between an autonomous surface vehicle connected to an ROV including the umbilical management system. Such a platform could be used for underwater intervention operations with a degree of autonomy much higher than the one currently known in the state of the art.

Requirements: Good programming skills (Matlab and C ++); Good knowledge of robot modeling, navigation, guidance and control of autonomous robots.

References:
Fossen, Thor I. Handbook of marine craft hydrodynamics and motion control. John Wiley & Sons, 2011.

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11. Outlier robust state estimation methods for robotics and autonomous systems

Tutors:

Giovanni Indiveri
Marco Baglietto

Department:

Department of Informatics, Bioengineering, Robotics and Systems Engineering, University of Genoa
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Description:
State estimation in the presence of measurement outliers is a relevant and challenging issue in many applications. Likewise, fitting data to models in the presence of outliers as well as outlier identification are central topics in statistics. Indeed, the issues of robust model identification and state estimation are addressed in many research areas including statistics, computer vision, and automatic controls. Highly performing approaches for outlier robust data fitting and model identification as the Least Median of Squares (LMS) or the Least Trimmed Squares (LTS) are intrinsically batch algorithms [1]. They cannot be easily implemented recursively as required for online state estimation applications.

The objective of the PhD proposal is two-fold: the former is to investigate and compare existing outlier robust state estimation methods and their applicability to robotic and autonomous systems navigation and control systems; the latter is to study, implement and test innovative outlier robust state estimation filters based on a receding horizon paradigm as applied to optimization criteria like LMS, LTS or the Least entropy-Like approach [2] that have been poorly analysed to date in state estimation scenarios.

Requirements:
Good programming skills (Matlab or C++); good background knowledge in systems theory and linear state estimation.

References:

[1] Rousseeuw PJ, Leroy AM. Robust Regression and Outlier Detection. John Wiley & Sons: Hoboken, NJ, USA, 2003.

[2] Indiveri G. An entropy-like estimator for robust parameter identification. Entropy 2009; 11(4):560–585

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12. Machine learning methods for active identification

Tutor:

Marco Baglietto

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Description:

The research will focus on system identification methods with particular attention to the role of the control action to improve (on line) the performance in terms of identification accuracy over a finite time or time. As for the system model, the so-called "black box" paradigm will be addressed. No specific structure for the system to be identified will be assumed.

Machine learning methods will be addressed. Use of parametrized approximation structures will be considered whose complexity could be tuned a priori in order to reach a suitable trade-off between model accuracy and online computational requirement. The parameters of the approximating structure will be tuned on line, when the control action will be used in order to improve the achieved model accuracy. Different control methods will be addressed, based on parameterization of the control laws as well as on approximate optimization methods.

Requirements:

Skills in system identification, machine learning, optimal control.

References:

[1] L. Scardovi, M. Baglietto, T. Parisini, "Active State Estimation for Nonlinear Systems: a Neural Approximation Approach", IEEE Trans. on Neural Networks, vol. 18, no. 4, pp. 1172-1184, 2007.
[2] A. Alessandri, M. Baglietto, G. Battistelli, M. Gaggero "Moving-horizon State Estimation for Nonlinear Systems Using Neural Networks", IEEE Trans. on Neural Networks, vol. 22, no. 5, pp. 768-780, 2011.
[3] M. Z. Babar, M. Baglietto, "Optimal feedback input design for dynamic nonlinear systems",International Journal of Control, 2019. DOI: 10.1080/00207179.2019.1701711

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13. Cognitive architectures for human-robot collaboration

Tutors:

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Description:

Collaborative robots in manufacturing scenarios have been proposed to be deployed alongside human operators to perform a series of tasks traditionally considered stressful, tiring or difficult. Recently, we have proposed a comprehensive human-robot collaboration (HRC) framework called FlexHRC [1, 2], showing interesting results on the Baxter dual-arm robot and on cooperative mobile manipulators [3], while maintaining a *uniform* control architecture based on task priority [4].

The goal of this research proposal is to develop the new, cognitive-oriented version of FlexHRC, which will encompass the following directions.

1. Extending the capabilities of the task-priority control approach, with the aim of including force regulation, admittance schemes and integrating simulation-in-the-loop motion planning techniques.
2. Designing new approaches based on Task-Motion Planning, and therefore integrating high-level, continuous-discrete, planning frameworks, e.g., based on PDDL+, with belief-space planning techniques.
3. Develop modules able to adapt the human-robot collaboration scheme on the basis of an assessment, done autonomously by the robot, of the activities carried out by human operators, for instance to easy their fatigue or to perform actions on their behalf should these be difficult to them [5].

The overall goal is to design a novel HRC framework capable of exhibiting rich cognitive capabilities as far as human-robot collaboration is concerned. As a consequence, the development aspects will involve state-of-the-art software engineering methodologies to attain a novel framework usable in different configurations, e.g., dual arm robots and/or mobile manipulators. The framework will use improved techniques at the action sequencing and execution levels, and will show integrated capabilities in executing high-level (i.e., discrete) actions via low-level (i.e., continuous) behaviours, adapting the overall execution of such low-level behaviours to better adapts to human behaviour.

The PhD student will work within an engaging, stimulating, and multi-cultural environment. He or she will be involved in the activities carried out by two involved research teams, namely GRAAL and TheEngineRoom. This will involve also helping the teams supervise MSc students in their thesis work, most notably students from the UniGe's Robotics Engineering program. To conduct the research activities, the PhD student will use state of the art dual arm manipulators (a Baxter robot from Rethink Robotics and Tiago++ from PAL Robotics), a network of RGB-D devices, motion capture systems (two combined OptiTrack systems), wearable devices (both commercial and custom IMUs, custom data gloves), AR/VR equipment (an Oculus Rift, a Hololens2), as well as advanced computational machinery.

Requirements:

Sought applicants have good knowledge in rigid body kinematics and dynamics, as well as on robot control, artificial intelligence (including deep learning), excellent C/C++ skills, including also software engineering aspects, and a strong motivation for challenges.

References:

[1] K. Darvish, F. Wanderlingh, B. Bruno, E. Simetti, F. Mastrogiovanni, G. Casalino. Flexible human–robot cooperation models for assisted shop-floor tasks. Mechatronics, vol. 51, pages 97-114, 2018.
[2] K. Darvish, E. Simetti, F. Mastrogiovanni, G. Casalino. A hierarchical architecture for human-robot cooperation processes. IEEE Transactions on Robotics, vol. 37(2), pages 567-586, 2021.
[3] E. Simetti, G. Casalino, F. Wanderlingh, M. Aicardi. A task priority approach to cooperative mobile manipulation: theory and experiments. Robotics and Autonomous Systems, vol. 122, 103287, 2019.
[4] E. Simetti, G. Casalino. A novel practical technique to integrate inequality control objectives and task transitions in priority based control. Journal of Intelligent and Robotic Systems: Theory and Applications, vol. 84(1-4), pages 877-902, 2016.
[5] Careful with that! Observation of human movements to estimate object properties. Proc. of the 13th Int. Workshop on Human-friendly Robotics (HFR), Anywhere on Earth, October 2020.

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14. Advanced robot manipulation skills acquired via human demonstrations

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Description:

Humans excel in the manipulation of everyday objects or tools, especially when learning new manipulation skills, or when adapting already acquired skills to different tasks. Such an expert ability to use the hands for manipulation results from a life-long learning process that draws upon the observation of other humans as well as ourselves, as we discover how to handle objects first hand.

Today's manipulation capabilities in robots are unable to achieve such high level of dexterity in comparison to humans, and acceptable results are obtained only in very specific application scenarios and use cases [1]. In order for robots to operate reliably in environments *made by humans and for humans*, They must be capable of manipulating a wide variety of unknown objects modulating different parameters, such as contact strength, motion dexterity, and grasp stability. Furthermore, an object or tool may be considered (and therefore perceived) not only for its physical features, but also for the possibilities it entails, i.e., its *affordances*.

The need arises to provide robot hands with high-end behavioural capabilities, and specifically to deal with real-world uncertainties in perception and action, to represent heterogenous, multi-modal (visual and haptic) object features, and to generalise previously acquired manipulation skills to new objects and tools, and for new tasks.

This PhD proposal aims at (i) understanding how humans perform in-hand object manipulation, and at (ii) replicating the observed skilled movements with dexterous artificial hands. The work will merge the concepts of reinforcement and transfer learning to generalise in-hand manipulation skills to previously unknown objects, tools, and tasks, starting from well-known experiments as those done in the Open AI Gym scenario[6], which will be considered as a simulation platform in this PhD research proposal. An abstract representation of previously acquired knowledge, e.g., based on logic-based or belief-space frameworks [2], will be fundamental for

[6] For instance, see the Open AI page https://gym.openai.com/envs/HandManipulateBlock-v0/ for block-like object manipulation, and https://gym.openai.com/envs/HandManipulatePen-v0/ for a pen-like object.

reproducing acquired (learned) skills to different robot hand's mechanical shapes. The learning process will use heterogeneous, multi-modal data that will be collected, annotated and assembled into a large dataset, using an ad-hoc setup involving different sensing modalities [3]. The data and the methods developed throughout the PhD research period will be shared with the whole research community to allow for testing against open benchmarks and reproduction of results.

The core objectives of the PhD proposal are:

1. to build a visuo-haptic multi-modal robot perception architecture that extracts data about object manipulation via human demonstration;
2. the creation of a multi-modal dataset of in-hand manipulation tasks including re-grasping, reorienting and fine repositioning;
3. the development of an advanced object modelling and recognition method, including the characterisation of object's physical properties and their affordances;
4. to autonomously learn and precisely imitate human strategies in manipulation tasks.

The PhD student will work within an engaging, stimulating, and multi-cultural environment. He or she will be involved in the activities carried out by the TheEngineRoom team. This will involve also helping the team supervise MSc students in their thesis work, most notably students from the UniGe's Robotics Engineering program. To conduct the research activities, the PhD student will use state of the art dual arm manipulators (a Baxter robot from Rethink Robotics and Tiago++ from PAL Robotics, the latter provided with a dexterous 10-DOF hand), a network of RGB-D devices, motion capture systems (two combined OptiTrack systems), wearable devices (both commercial and custom IMUs, custom data gloves), AR/VR equipment (an Oculus Rift, a Hololens2), as well as advanced computational machinery.

This work will be done in the context of the H2020 CHIST-ERA collaborative project InDex. The student will have the opportunity to spend research periods abroad at Aston University (UK), Sorbonne University (France), TU Wien (Austria), and the University of Tartu (Estonia).

Requirements:

- Notions related to machine learning, data analysis, trajectory and motion planning.
- Software development in C/C++.

References:

[1] L. Seminara, P. Gastaldo, S. J. Watt, K. F. Valyear, F. Zuher, F. Mastrogiovanni. Active haptic perception in robots. Frontiers in Neurorobotics, vol. 13, 53, 2019.

[2] A. Thomas, F. Mastrogiovanni, M. Baglietto. MPTP: Motion-Planning aware Task Planning for navigation in belief space. Robotics and Autonomous Systems (accepted), 2021. Preprint at: https://arxiv.org/pdf/2104.04696.pdf.
[3] A. Carfì, F. Foglino, B. Bruno, F. Mastrogiovanni. A multi-sensor dataset for human-human handover. Data in Brief 22, 2019.

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15. Robot cognitive architectures based on quantum computing

Tutors:

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Description:

Formalisms inspired by quantum theory have been used in Cognitive Science for decades. Indeed, quantum-like approaches provide descriptive features which are inherently suitable for perception, cognition, and decision making. With the free availability of quantum computing backends, such as the IBM Quantum Experience [1], it is now possible to start developing software applications taking advantage of this new computational paradigm.

In the past year, we conducted preliminary studies on the feasibility of quantum-like perception models for robots with limited sensing capabilities [2]. These preliminary studies have been extended to multi-sensory inputs with the aim of generating a 3D, quantum-like, multi-dimensional representation of the robot environment directly based on sensor readings [3]. In particular, it has been shown how quantum-like cognitive models provide a compact and elegant representation, embodying features which are extremely useful to model uncertainty, and define operators to inspect any world state, which quantifies the robot's degree of belief in that state.

The goal of this PhD research proposal is to design and develop a complete, quantum-like, cognitive architecture for robots. It is envisaged that the students will carry out the following activities:

1. Design an appropriate quantum-like formalisation to express robot cognitive processes related to perception, knowledge representation, reasoning, and action.
2. Starting from a framework developed in the last year [4], design and develop a novel, quantum-like, general purpose cognitive robot architecture allowing a robot to perceive its environments, maintain a set of beliefs about it, and perform goal-oriented decision making.
3. Perform validation on a selected number of use cases, possibly related to robot navigation and manipulation, with the aim of benchmarking with respect to existing models.

The resulting cognitive robot architecture will be the first of its kind.

The PhD student will work within an engaging, stimulating, and multi-cultural environment. He or she will be involved in the activities carried out by the TheEngineRoom team. This will involve also helping the teams supervise MSc students in their thesis work, most notably students from the UniGe's Robotics Engineering program. To conduct research activities, the PhD student will use state of the art dual arm manipulators (a Baxter robot from Rethink Robotics and Tiago++ from PAL Robotics), a network of RGB-D devices, motion capture systems (two combined OptiTrack systems), as well as advanced computational machinery.

Requirements:

- Software development in C/C++/Python.
- Knowledge of quantum computing principles is a nice plus.

References:

[1] https://quantum-computing.ibm.com/.
[2] D. Lanza, P. Solinas, F. Mastrogiovanni. A preliminary study for a quantum-like robot perception model. arXiv:2006.02771, 2020. Available: http://arxiv.org/abs/2006.02771.
[3] D. Lanza, P. Solinas, F. Mastrogiovanni. Multi-sensory integration in a quantum-like robot perception model. Proc. 17th Int. Symposium on Experimental Robotics (ISER), Anywhere on Earth, 2021.
[4] http://www.quantum-robot.org/.

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16. Speech-capable Augmented Reality avatars to assist humans in daily activities

Tutors:

Alessandro Carfì
Fulvio Mastrogiovanni

Department:

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Description:

In the past few years, we have witnessed a renovated interested in Augmented Reality (AR), and in the related capabilities mediated by see-through displays to superimpose various forms of information on a human-centred first-person view. This perspective opens up unprecedented possibilities as far as the interaction between humans and cognitive systems is concerned, e.g., to design new forms of communication allowing such a system to better share its intentions to humans, or to provide them with context-aware instructions about how to cooperate with it or similar systems.

In this PhD research proposal, we want to investigate the role of speech-enabled AR avatars as *mediators* between a human wearing a see-through display and a cognitive system, which may be an intelligent, autonomous robot, an intelligent environment, or a non-embodied artificial intelligence *agent*. We want to enrich the communication experience between a human and a cognitive system by introducing an intelligent, context-aware AR avatar verbally and gesturally interacting with humans. Beside the appearance of the AR avatar, the PhD research project will focus on key linguistic theories to enforce the fruitfulness of the interaction, and in particular on aspects related to Politeness Theory [1, 2].

Starting from the work done in the context of the HoloBot project (web: https://github.com/ActiveNick/HoloBot), PhD candidates will have to achieve a set of milestones:

1. Design and develop the new generation of a cognitive architecture, initially developed for intelligent environment, to be deployed as a core component for intelligent robots, intelligent environments, or other classes of cognitive systems.
2. Formalise a computational framework considering relevant aspects of Politeness Theory in selected use cases involving interaction with a wide range of cognitive systems.

3. Encode using formal languages the previously developed computational framework, e.g., using logic-based (Boolean or Fuzzy Ontologies) techniques, or such probabilistic approaches as forms of graphical models.
4. Deploy the models within suitable chatbots-related technologies, such as for example the Google Meena framework [3].
5. Integrate the resulting chatbot with AR avatars.
6. Perform real-world validation in the developed use cases.

The PhD student will work within an engaging, stimulating, and multi-cultural environment. He or she will be involved in the activities carried out by the TheEngineRoom team. This will involve also helping the team supervise MSc students in their thesis work, most notably students from the UniGe's Robotics Engineering program. To conduct the research activities, the PhD student will use state of the art dual arm manipulators (a Baxter robot from Rethink Robotics and Tiago++ from PAL Robotics, the latter provided with a dexterous 10-DOF hand), mobile robots (an autonomous robot from Husqvarna and a Kuka YouBot), a system of multiple RGB-D devices, motion capture systems (two combined OptiTrack systems), wearable devices (both commercial and custom IMUs, custom data gloves), AR/VR equipment (an Oculus Rift, a Hololens2), as well as different instances of intelligent environments based on Kibi technology from Teseo srl, a spin-off company from the University of Genoa.

Requirements:

- Notions related to computational linguistics and ontology engineering.
- Software development in Python.
- Experience with chatbot technology is a plus.

References:

[1] P. Brown and S.C. Levinson. Politeness: some universals in language usage. Cambridge: Cambridge University Press, 1987.
[2] L. Buoncompagni, A. Capitanelli, M. Cristofanini, A. Giuni, F. Mastrogiovanni, Carola Motolese, A. Nisticò, A. Sperindè, R. Zaccaria. Persuasive and polite sentences to drive human-robot interaction in smart homes for elderly care. Proc. of the 7th Italian Workshop on Artificial Intelligence and Robotics (AIRO), November 2020.
[3] https://arxiv.org/abs/2001.09977

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17. Augmented Reality approaches in robot-assisted surgery

Tutors:

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Description:

Robot-assisted surgery represents one of the major real-world achievements of robotics technology reached so far [1]. The availability of the Da Vinci robot from Intuitive Surgical has unlocked an unprecedented potential in intra-operative surgical setting by allowing surgeons to be projected inside a person's body via a 3D camera, and providing them with incredible precisions as far as intra-body navigation is concerned via hand and foot control, which would not be attainable otherwise with conventional laparoscopic instruments. While looking at a magnified 360 degree view of the operative field, the surgeon remotely moves the robot arms attached to surgical instruments [2].

In this PhD research proposal, we want to extend this support the surgeons further, by providing them with augmented visual information in their magnified 360 degree view. We want to superimpose such magnified view with a 3D model of the organ currently under surgery, previously obtained by PET or CT scans, in order to enable visibility of organ parts not visible in the magnified view. The 3D organ model's pose and deformation will be tracked during the whole surgery process [3]. In particular, PhD candidates will have to work on the following tasks:

1. Design and develop a distributed hardware/firmware/software architecture to obtain information related to the 3D organ model's posture, orientation, and deformation.
2. Design and develop model-driven and data-driven computational models for organ pose and deformation tracking.
3. Investigate appropriate techniques to present superimposed, augmented data to surgeons during the intra-operative procedure.
4. Perform real-world validation with a Da Vinci robot in a controlled environment.

The PhD student will work within an engaging, stimulating, and multi-cultural environment. He or she will be involved in the activities carried out jointly by the TheEngineRoom team and the Urology Clinic and the San Martino Polyclinic in Genoa, in particular with Prof. Carlo Terrone and Prof. Paolo Traverso. This will involve also helping the team supervise MSc students in their thesis work, most notably students from the UniGe's Robotics Engineering program. To conduct the research activities, the PhD student will use a Da Vinci robot from Intuitive Surgical hosted in one of the operating room at the San Martino Polyclinic, and as a mock-up a state of the art dual arm manipulator, a system of multiple RGB-D devices, motion capture systems (two combined OptiTrack systems), wearable devices (both commercial and custom IMUs, custom data gloves), as well as AR/VR equipment (an Oculus Rift, a Hololens2).

Requirements:

- Firmware/software development in C/C++.
- Hardware design.

References:

[1] B. Crew. Worth the cost? A closer look at the Da Vinci robot's impact on prostate cancer surgery. Nature 580, S5-S7, 2020.
[2] A. Navaratnam, H. Abdul-Muhsin, M. Humphreys. Updates in urologic robot assisted surgery. F1000Res. 2018;7:F1000 Faculty Rev-1948, 2018.
[3] F. Mastrogiovanni, C. Terrone, P. Traverso. Apparato di rilevazione e tracciamento della postura e/o della deformazione di un organo corporeo. Italian Patent Application number 10202000015322.

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18. Robotics technologies for unstructured environments (funded by LEONARDO Company)

Department:
Leonardo Labs (Link) in collaboration with Department of Informatics, Bioengineering, Robotics and Systems Engineering, University of Genova.

Description:
The goal of the research is to enable the next wave of robots to succeed into uncontrolled environments (in which the tasks are unknown, such as in disaster response, emergency operations and space exploration) through progress in a number of key technologies integrated in advanced robotic prototypes that can demonstrate the capacity to execute the first realistic missions.

The PhD student will work at Leonardo Lab (Genova) in collaboration with the research staff of Leonardo Company and DIBIRS.

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19. Robotics and Applied Artificial Intelligence (funded by LEONARDO Company)

Department:
Leonardo Labs (Link) in collaboration with Department of Informatics, Bioengineering, Robotics and Systems Engineering, University of Genova.

Description:
The goal of the research is to create robotic systems embedded with human-in-command artificial intelligence, which can function autonomously or in collaboration with humans in complex application scenarios.

The PhD student will work at Leonardo Lab (Genova) in collaboration with the research staff of Leonardo Company and DIBIRS.

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